Space Shuttle Lessons Learned Knowledge Sharing Forum

NASA KSC Lesson Learn Entry: 3236
Solid Rocket Booster (SRB)
Flame Trench Refractory Failure Modes

Gabor Tanacs
Armand Gosselin

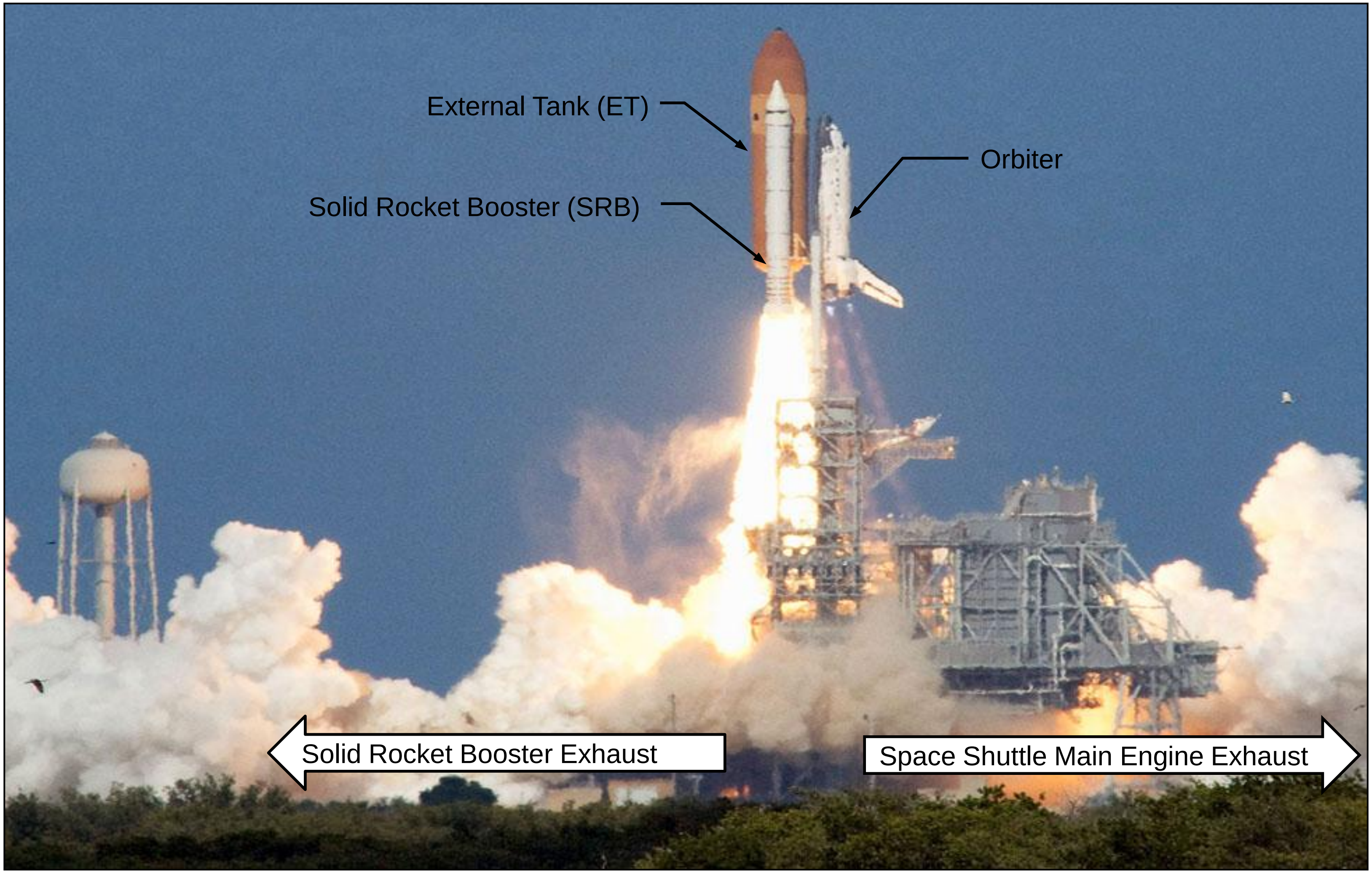
USA L&RS Engineering

January 27, 2011

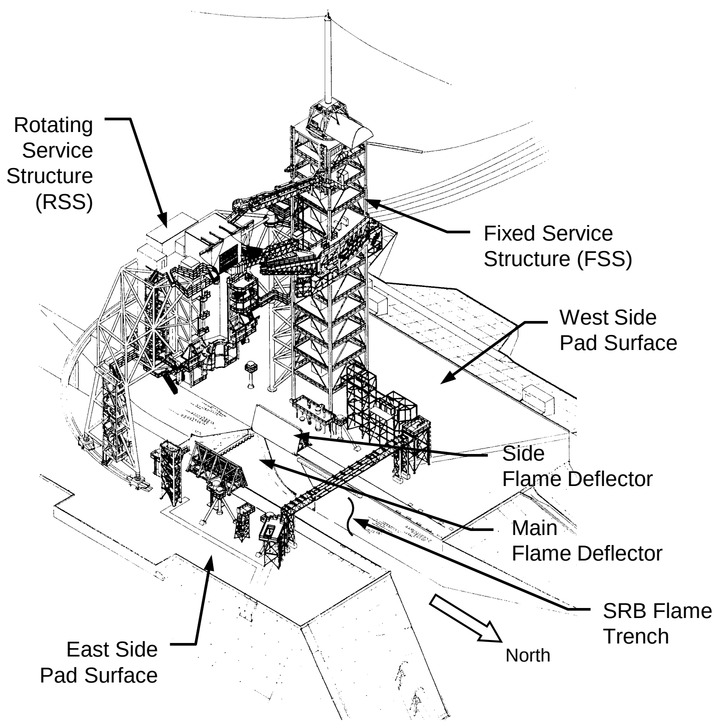
Problem Definition

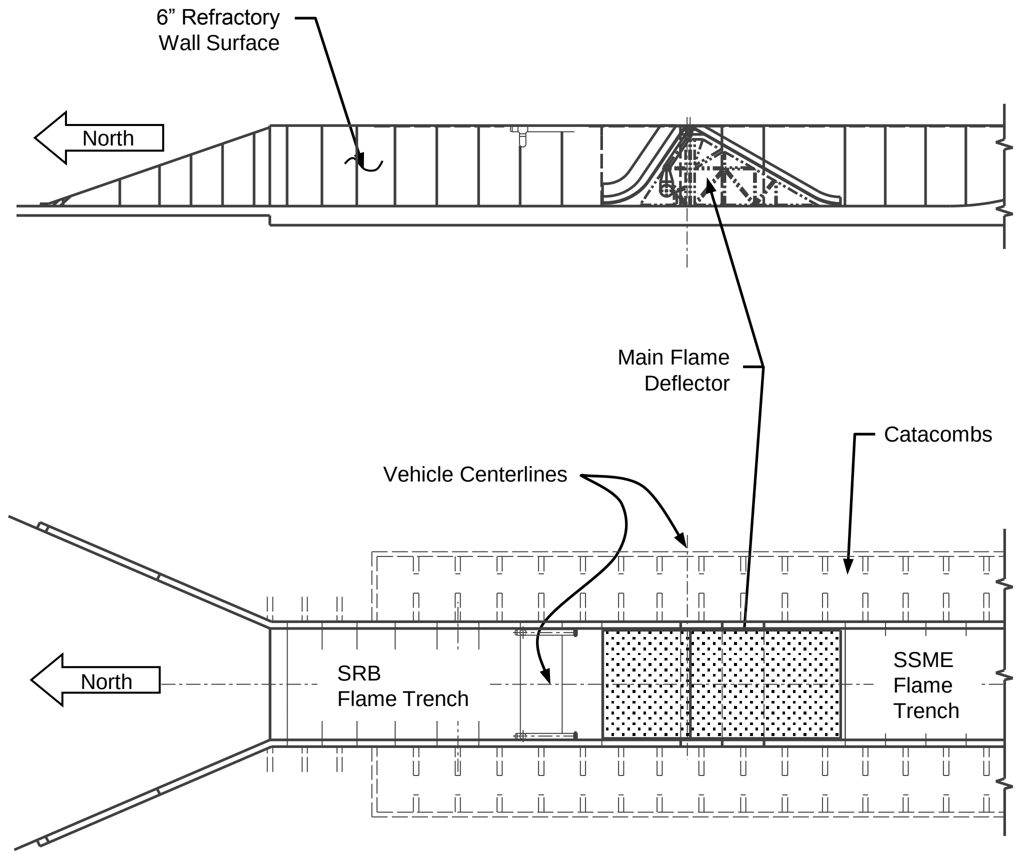
- During the launch of STS-124, over 3,500 of the 22,000 interlocking refractory bricks that line the east wall of the SRB Flame Trench were liberated from Pad 39A
- The STS-124 launch anomaly generated an agency-wide initiative in order to determine root cause, assess vehicle safety, ground support equipment (GSE) safety and reliability, and to determine corrective action
- The investigation encompassed:
  - Radar imaging
  - Infrared video review
  - Debris transport evaluation
  - Computational fluid dynamics (CFD)
  - Non-destructive evaluation (NDE)
  - Analysis in order to validate the corrective action

Space Shuttle Launch and Systems

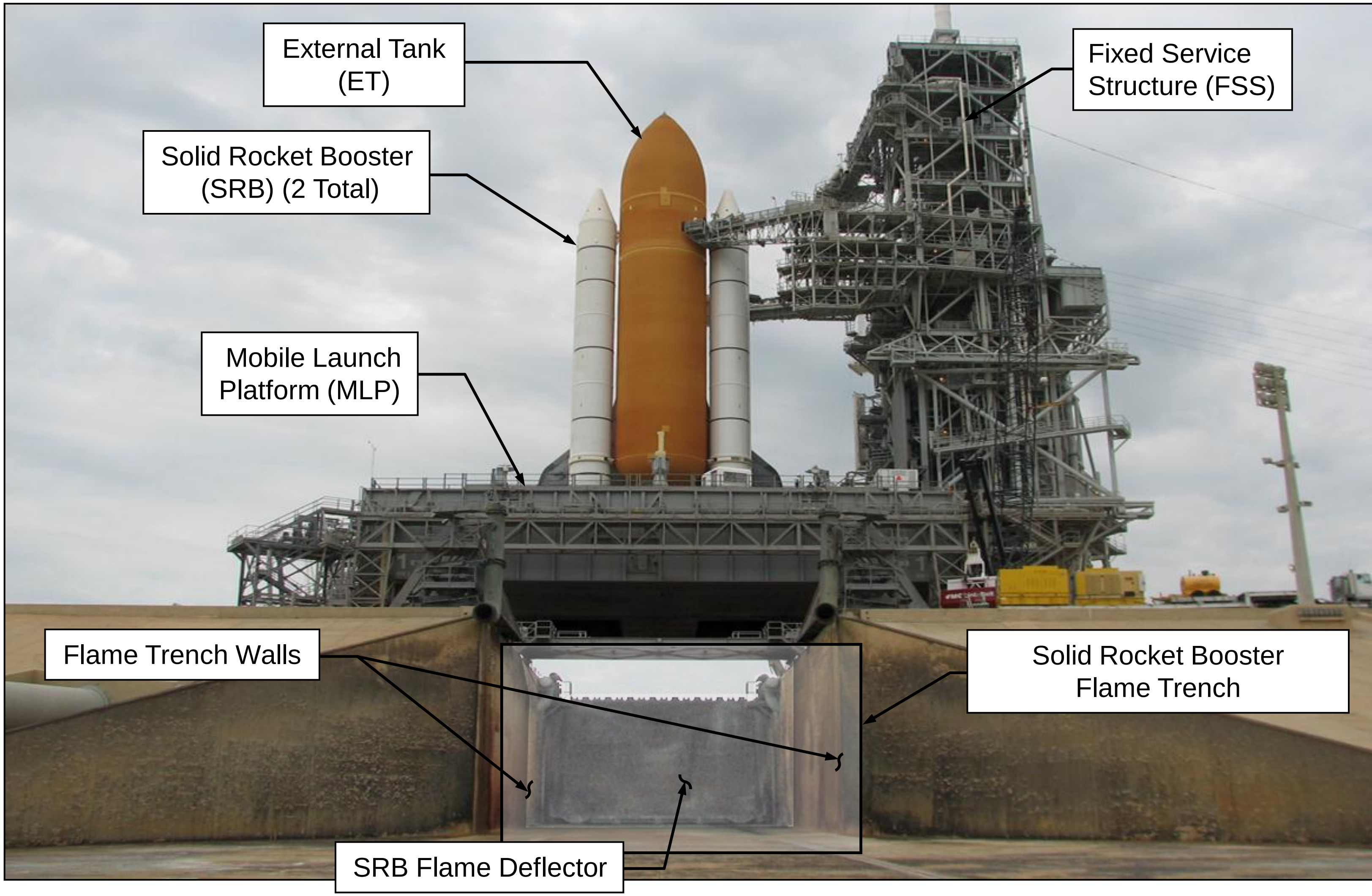


Complex 39, Launch Pad Flame Trench Configuration

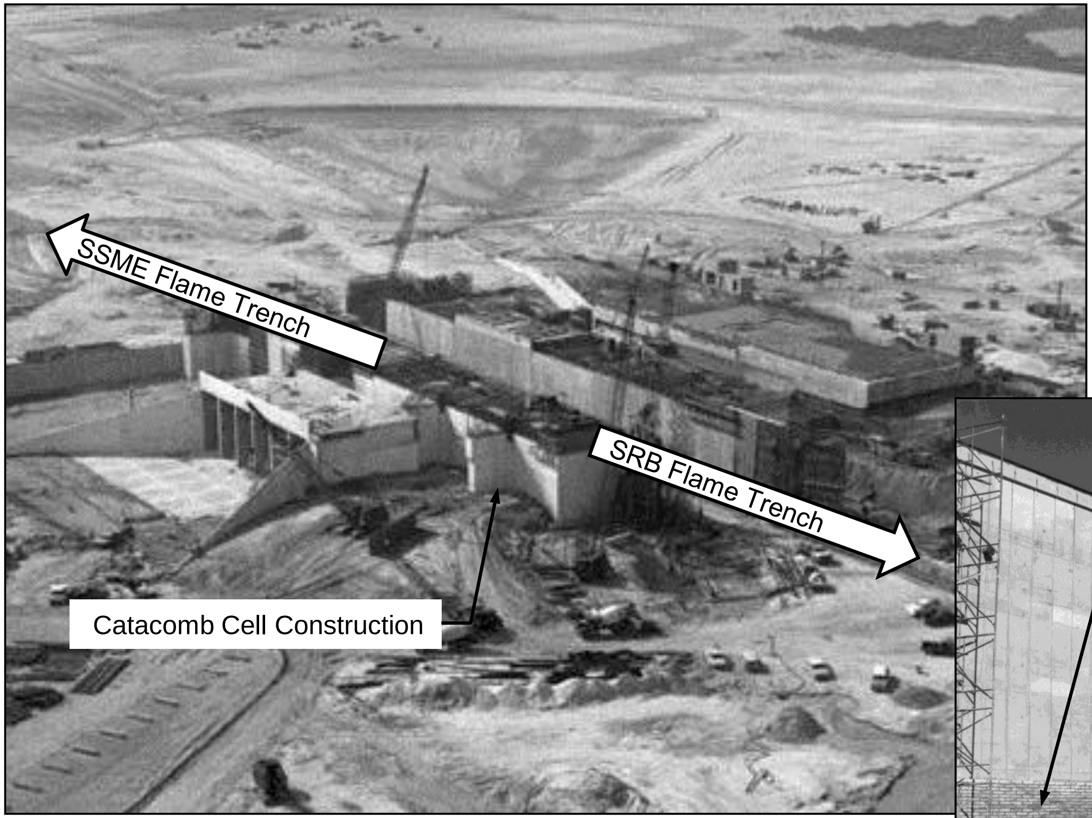


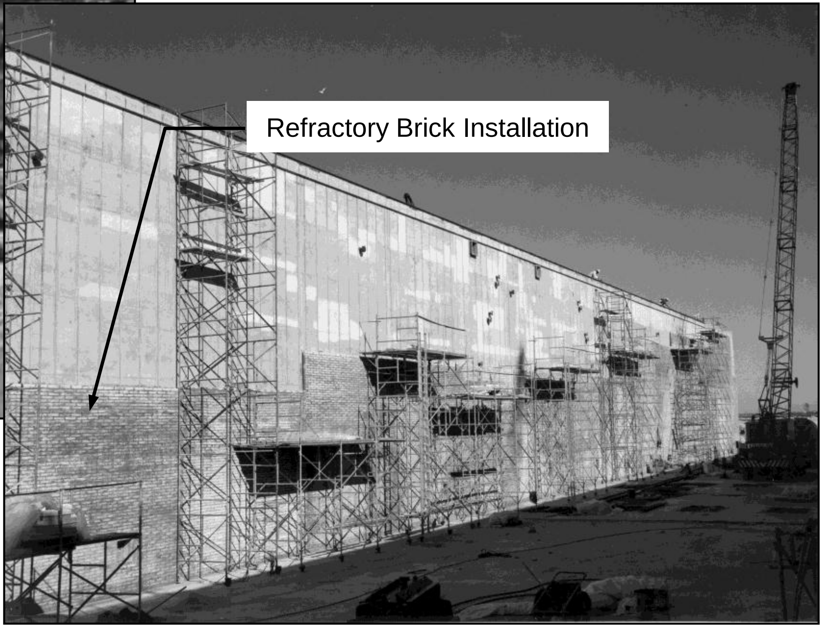


Launch Complex 39 Pad A SRB Flame Trench – Looking South



Complex 39, Pad A Flame Trench Construction ~ 1964

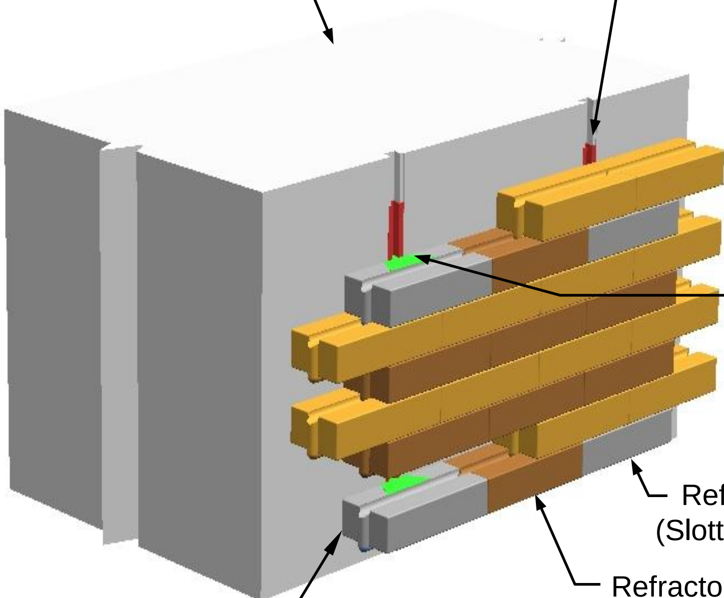


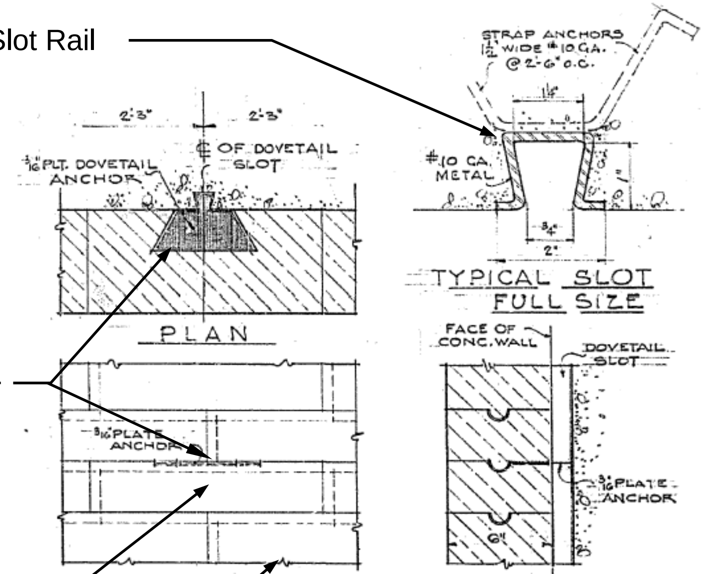


Flame Trench Wall Refractory Brick Configuration

Concrete Retaining Wall

Dove Tail Anchor Wall Slot Rail





Dove Tail Anchor

Refractory Wall Brick
(Slotted – Dove Tail Slot)

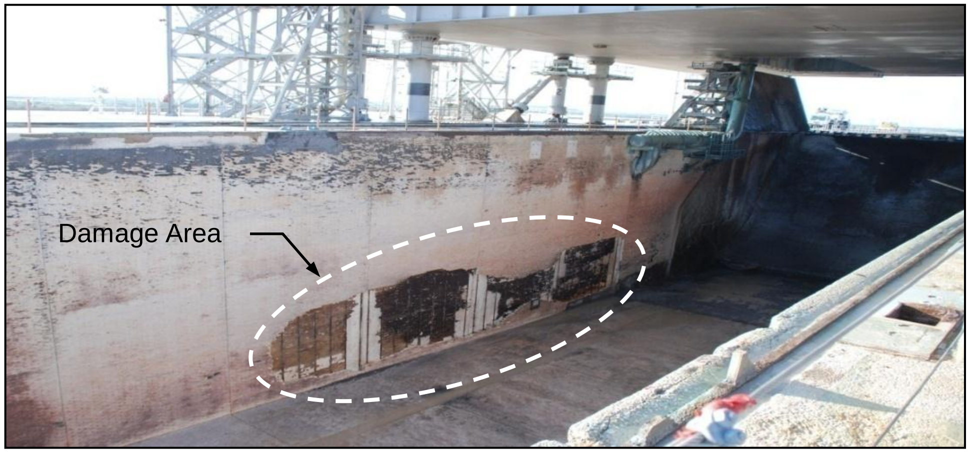
Refractory Wall Brick
(Non-Slotted)

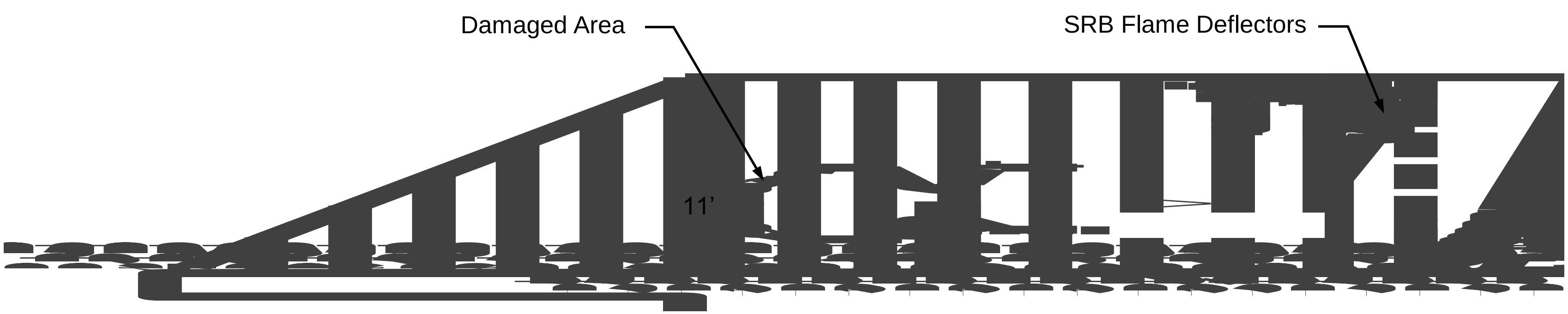
Epoxy/Mortar Bond

Typical Worn Refractory Brick

Flame Trench East Wall Damaged Area

- **East Brick Wall Damage**
  - **Estimated Total Bricks On East Wall ~ 22,000**
  - **Estimated Lost Bricks ~ 3,540 (16% Loss of East Wall)**





Brick Impact Mapping

- **Perimeter Fence Damage**
  - **Fence at ~1800 ft from damage initiation**
- **Bricks Beyond Perimeter Fence**

Flow Direction

Flow Direction

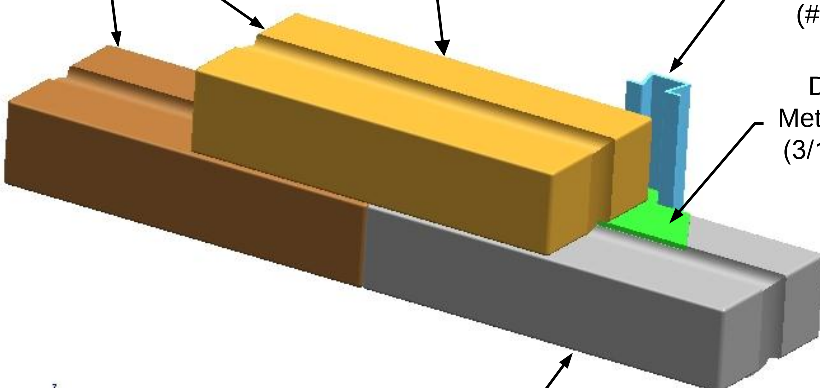
Flow Direction

Description of Driving Event

- Radar tracking showed some of the bricks were ejected at about 680 mph but, because of their location and direction of travel, did not damage flight hardware
- An inspection found that:
  - The dovetail anchor plates and metal wall slot rails used to secure the refactory bricks to the concrete back wall were heavily corroded
  - Mortar between brick joints had eroded
  - The epoxy applied to help secure the bricks to the wall was degraded
- When the pad catacomb walls were constructed in the ‘60s imperfections in the straightness of the concrete surface were fixed using a mortar skim mix to which the epoxy was applied
  - This mortar skim mix contributed to the de-bonding

Description of Driving Event (continued)

- **Brick-to-Wall Bond Failure**
  - **Dovetail Anchor Plate Corrosion**
  - **Epoxy Degradation**



Description of Driving Event (continued)

- For years, the health of the brick portion of the flame trench was determined by measuring surface erosion
  - Surface erosion, to the point where an inch or greater of brick remained from the tongue-and-groove to the face of the brick, was considered structurally sound
  - Without other information from which to work, the condition of the metal wall ties and the epoxy could not be determined.

Description of Driving Event (continued)

- The flame trench refractory brick system was designed for the Saturn Apollo program, which had a liquid fuel propulsion system, and was grandfathered into use in the Shuttle program, which has a solid fuel propulsion system
  - This was done without a detailed definition of the loads and environments, an inspection plan, or a good set of calculations or assumptions derived from the Saturn design parameters
  - The liquid fuel propulsion system generated more heat because the flight vehicle was held down until enough thrust was achieved for launch
  - With the solid fuel propulsion system, the launch vehicle ascends from the pad fairly quickly; and with the water from the sound suppression system, there is less direct heat impingement

Description of Driving Event (continued)

- With the solid fuel propulsion system the overall environment is worse
  - Materials are heated, then cooled with the sound suppression water
  - The solid propellant residue (aluminum oxide) is abrasive
  - Another of its byproducts (hydrogen chloride) subjects the materials in the launch environment to a hydrochloric acid bath
  - The released water acts like a blanket to trap the acoustic energy of the SRB ignition below it, thus subjecting the materials and equipment below it to a more intense acoustic environment

Lessons Learned

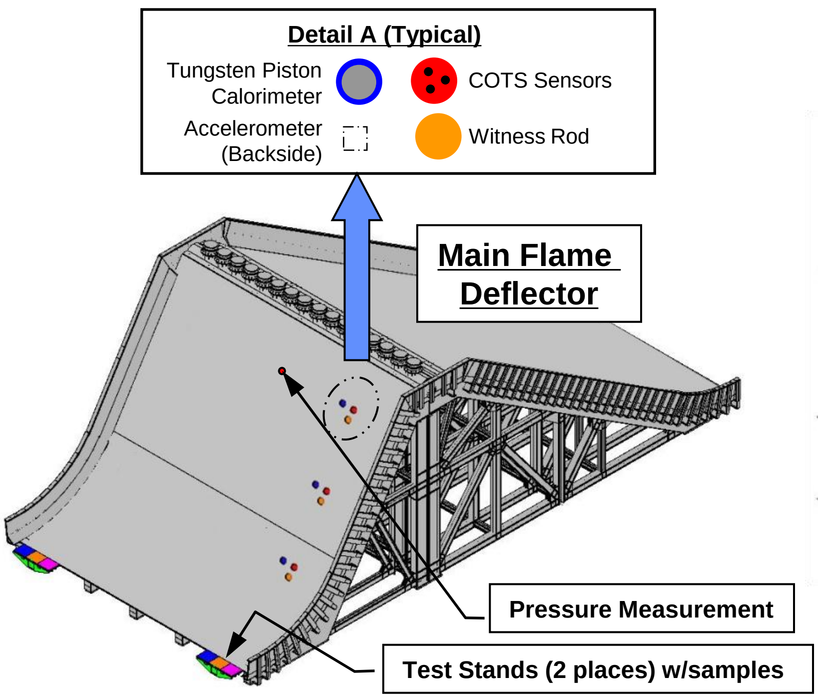
- The fact that a legacy system has never failed catastrophically does not guarantee that it will not fail in the future
- Detailed loads and environments need to be defined for design of new launch vehicle GSE and facilities
- More comprehensive inspection methods should have been used in order to detect material erosion when it was first becoming noticeable in the flame trench

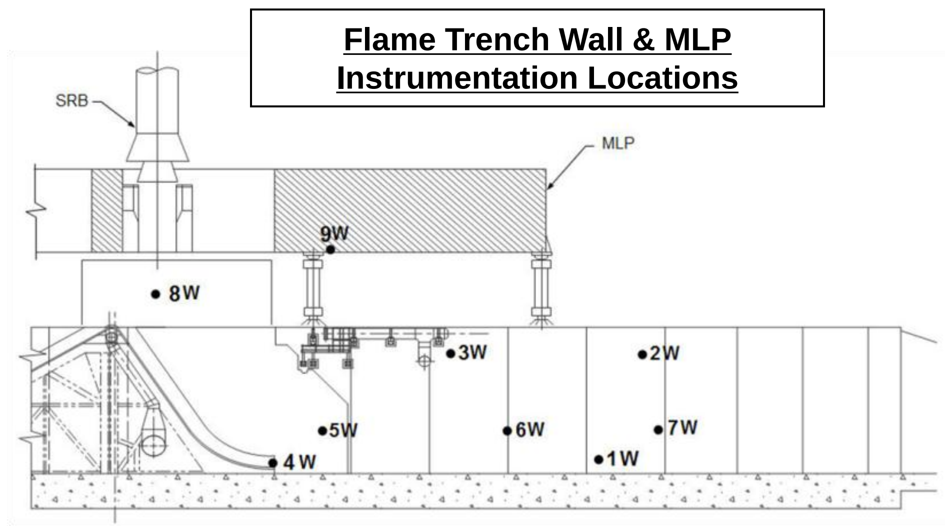
Recommendation

- Define the detailed loads and environments for future programs, and certify the flame trench systems for the launch pads that will be used with any new family of launch vehicles
- Perform a risk analysis for flame trench failure modes
- Develop inspection criteria, inspection methods, and maintenance and repair procedures for the flame trenches for both launch pads
- For a legacy system such as the flame trench
  - Obtain as much historical information and data as possible
  - Develop a test plan to validate the legacy system against new loads and environments
  - Test the performance of new types of refractory materials to see if these advancements can benefit the program

Evidence of Recurrence Control Effectiveness

- **A project has been established to gather data during the remaining launches by evaluating two alternative refractory materials on a test stand attached to the SRB main flame deflector**
- **The Flame Trench and Main Flame Deflector have been instrumented to better understand any deltas between the predicted and actual launch environment parameters**





Reference Documents

- Flame Trench Refractory Failure Modes
  - Lessons Learned Entry: 3236
    - Lesson Date: 2010-06-1
    - Submitting Organization: KSC
    - Submitted by: Annette Pitt
    - POC Name: Michael Olka
    - POC Email: Michael.H.Olka@usa-spaceops.com
    - POC Phone: 321-861-9581
- STS-124 Pad 39A Launch Damage High-Visibility Type A Mishap Out Brief
  - IRIS Case Number: 2008-176-00002
    - Date of Mishap: May 31, 2008
    - Presenters: Miguel A. Rodriguez, MIT Chair
Gerald D. Schumann, Ex-Officio
    - Date of Briefing: July 15, 2008